Transition from Order to Chaos in rotational Nuclei

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Chaos in nuclei has been studied by measuring the energy intervals between the levels (the "nearest-neighbor distributions" and the "Δ_3 statistics" [1]) and the results show that near the neutron binding energy the behavior is essentially chaotic [2]; whereas, near the ground state it is mainly ordered [3]. We have developed a new method to trace the behavior between these points. We study Yb nuclei produced in heavy-ion fusion reactions, which bring high angular momentum and thermal excitation energy, E^*, into the fused system. Neutron evaporation quickly brings E^* down to about the neutron binding energy, and the angular momentum and remaining E^* are removed in a γ-ray cascade down to the ground state. This cascade covers the range between ordered and chaotic behavior in these nuclei and is the focus of our study. The Yb nuclei were chosen because nuclei in this region are deformed and exhibit rotational behavior which is essential for our method.

We have studied the narrow (valley-ridge) structure that appears in gated γ-ray spectra following heavy-ion fusion reactions and have shown that the intensity of this structure can be quantitatively related to the ratio, v/d, where v is the average interaction between the states and d is the average energy separation between adjacent states. It has been shown that v/d is, in turn, related to the chaotic behavior of a system [4]. We were able to trace the behavior from nearly fully ordered to nearly fully chaotic. The results are shown in Fig.1.

It is important to note that measuring the intensity of this narrow structure does not require the separate identification of compound-damped and discrete γ rays. Both of these γ-ray types arise from events that enter and decay via the same component of the wave function and they produce similar structures in the spectrum. We use a simulation code [5] to determine the intensity of this structure, but this measurement does not rely on the use of such a code provided the statistical γ rays are removed, and the spectrum is unfolded to remove Compton-scattered γ rays.

This is a new way to explore the order-to-chaos transition in nuclei. It looks directly at a property of the wave function rather than at level spacings and can often be used where measuring the energy-level spacings is not possible. There are two obvious ways to extend these measurements. The first is to use experimental tags (some kind of channel selection) to define more specific decay pathways and thus provide better information on variables like E^*. The second is to make the simulations better and more reliable so we can extract and use more information from them. It would also be interesting to look for other correlated quantities (like our γ-ray emissions) that could be exploited in this way to provide information on chaotic behavior or other properties.

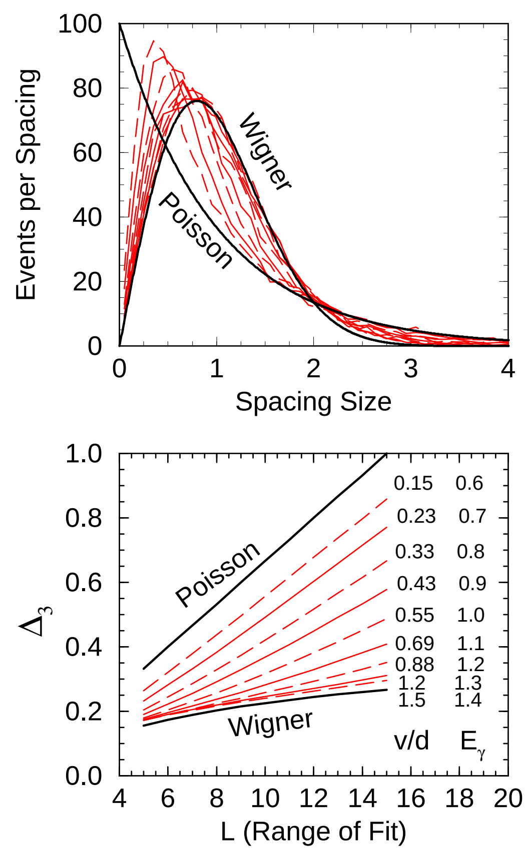

FIG. 1: The distributions, NND (upper) and Δ_3 (lower), for the measured v/d values (indicated) together with the Poisson and Wigner limits (heavy lines). Starting with the first gate alternate gates are dashed to help distinguish them. The γ-ray gate energy associated with each v/d value is also indicated on the figure.

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